Met.O.785
METEOROLOGICAL OFFICE

the meteorological magazine

DECEMBER 1967 No 1145 Vol 96
Her Majesty's Stationery Office

METEOROLOGICAL OFFICE Met.O.785

THE METEOROLOGICAL MAGAZINE

Vol. 96 No. 1145, December 1967

551.524.36(422):551.588.7

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By D. M. LOVE

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It was thought originally that there would be considerable differences between the temperatures recorded, because of the different nature and exposure of the two sites. Casual inspection seemed to show that the variations were not nearly so great as might have been expected, therefore a more detailed comparison was undertaken.

Two full years' observations, 1963–64, were studied for differences in maximum and minimum temperatures, in much the same way as was done for London temperatures by Marshall.[1]

Exposures.—The climatological station in East Park is an orthodox grass-covered enclosure at a height of 65 ft above sea level. The exposure, while fairly good for an urban site, is not ideal, the enclosure being on a slight mound, about three feet above the general level, almost completely surrounded by a thick holly hedge 4 ft 6 in high, and with trees in the surrounding park sheltering the site to some extent. At its nearest point, the holly hedge is about 16 ft distant from the thermometer screen.

The Weather Centre roof is asphalt-covered, over a 'pot' sub-structure filled with ventilated vermiculite. It is 33 ft above street level and 61 ft above sea level, and is part of a long, nearly level roof lying almost north–south. To the north, about 100 ft away, the pitched roof of a neighbouring building rises to a height of some 15 ft above the site level. To the south there is about 200 ft of almost level roof before any obstruction is reached, and this is only about 6 ft above the general level. At the south-west corner, just off the main roof, the anemometer lattice tower rises to 16 ft with the retractable mast extending to 30 ft above the site level. About 75 yd distant to the south-west is a large block of flats, which subtends an azimuth of 22° at the sunshine recorder and is about 110 ft higher than the site. Solid brick parapets run along the east and west sides, 2 ft 2 in high on the west and 3 ft 5 in on the east.

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The large thermometer screen stand was modified so that the thermometer bulbs are four feet above the roof surface, and is sited centrally between the east and west parapets.

Both sites, therefore, are at almost the same height above sea level. The main differences between them are the nature of the surfaces — grass and asphalt — and the more open aspect of the roof site at its height of 33 ft above street level.

Maximum temperatures.—The monthly means of the 24-hour maximum temperatures (0900–0900 GMT) at the two sites, for each year, and the differences between them are shown in Table I.

TABLE I—MONTHLY MEAN 24-HOUR MAXIMUM TEMPERATURES

	1963 East Park °F	1963 Weather Centre °F	1963 Difference* degF	1964 East Park °F	1964 Weather Centre °F	1964 Difference* degF
January	34·2	34·4	−0·2	44·2	43·8	+0·4
February	37·8	37·9	−0·1	47·4	46·4	+1·0
March	51·1	49·7	+1·4	47·3	46·3	+1·0
April	57·0	55·8	+1·2	56·4	54·6	+1·8
May	61·7	60·6	+1·1	66·1	64·5	+1·6
June	68·7	67·5	+1·2	67·5	66·1	+1·4
July	69·4	68·2	+1·2	72·9	71·7	+1·2
August	67·8	66·4	+1·4	71·8	70·6	+1·2
September	65·9	64·8	+1·1	69·9	68·5	+1·4
October	59·7	58·9	+0·8	58·3	57·0	+1·3
November	55·5	54·5	+1·0	53·9	53·2	+0·7
December	42·9	42·8	+0·1	46·8	45·9	+0·9
Year	56·0	55·1	+0·9	58·5	57·4	+1·1

* East Park values minus Weather Centre values.

Only in the exceptionally severe months of January and February 1963 were the monthly mean maxima higher at the Weather Centre than at East Park. During this period 'snow lying' was reported at the park every day from 1 January to 6 February, and again on 16 February and from 19 to 21 February. While observations of state of ground were made at the Centre, it is not possible to compare these with the park enclosure, as salt was applied to the roof at frequent intervals as a safety measure. It can be reasonably assumed that, for most of the time, there was little or no snow in the immediate vicinity of the roof screen whereas snow was lying in the park enclosure, and this could account for the higher roof maxima. In other months there seems to be a tendency for greater mean differences ($>+1$ degF) from April to September, with smaller differences in December and January, but no regular pattern is obvious.

Table II summarizes the daily differences between the sites over the two years, the readings having been rounded off to the nearest whole degree.

It will be seen that the frequency of differences within the range $+0·5$ to $-0·5$ degF was 26·5 per cent. Park maxima higher than roof values by 0·5 to 2·5 degF occurred on 62 per cent of the days, and on only 6·3 per cent of occasions were differences greater than 2·5 degF.

Of the 37 days when the roof maxima were the higher, 17 occurred in the severe months of January and February 1963. Differences ranging between $-1·5$ and $-2·5$ degF were the greatest observed (four occasions).

TABLE II—DAILY DIFFERENCES OF 24-HOUR MAXIMUM TEMPERATURES, 1963–64

Difference* degF	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
	number of occasions													*per cent*
+5							1						1	0·1
+4					1	2	1				1	2	7	0·9
+3	1	1	4	12	5	3	2	5	3	2	1		39	5·3
+2	1	6	20	18	21	24	17	19	17	17	11	2	173	23·7
+1	14	20	25	18	24	14	26	28	35	26	27	23	280	38·3
0	34	22	12	11	9	15	14	10	4	15	19	29	194	26·5
−1	11	7	1	1	2	1	1		1	2		6	33	4·5
−2	1	1				1					1		4	0·5

*East Park values minus Weather Centre values. The 24-hour period starts and ends at 0900 GMT

This is remarkably good agreement between sites of such different character.

Minimum temperatures.—Similar comparisons of minimum temperatures are set out in Tables III and IV.

In Table III the monthly mean differences are very consistent, both throughout each year and between corresponding months in the two years.

TABLE III—MONTHLY MEAN 24-HOUR MINIMUM TEMPERATURES

	1963			1964		
	East Park °F	Weather Centre °F	Difference* degF	East Park °F	Weather Centre °F	Difference* degF
January	23·8	24·9	−1·1	34·8	35·8	−1·0
February	28·2	29·1	−0·9	37·2	37·9	−0·7
March	38·1	38·9	−0·8	37·3	38·2	−0·9
April	42·7	43·3	−0·6	42·2	42·8	−0·6
May	44·6	45·6	−1·0	49·7	50·3	−0·6
June	52·9	53·4	−0·5	52·0	52·8	−0·8
July	53·5	54·3	−0·8	55·5	56·3	−0·8
August	53·5	54·3	−0·8	54·5	55·2	−0·7
September	50·9	51·6	−0·7	51·7	52·9	−1·2
October	48·0	48·9	−0·9	42·1	43·1	−1·0
November	44·6	45·7	−1·1	42·6	43·7	−1·1
December	32·8	33·9	−1·1	34·9	36·0	−1·1
Year	42·8	43·7	−0·9	44·5	45·4	−0·9

*East Park values minus Weather Centre values. The 24-hour period starts and ends at 0900 GMT.

TABLE IV—DAILY DIFFERENCES OF 24-HOUR MINIMUM TEMPERATURES, 1963–64

Difference* degF	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
	number of occasions													*per cent*
+4			1										1	0·1
+3						1						1	2	0·3
+2	2		1	1						2			6	0·8
+1		2		4	1	2		2	1	4			16	2·2
0	13	18	15	25	26	21	25	24	19	10	14	14	224	30·6
−1	30	26	37	19	22	28	26	24	27	27	27	27	320	43·8
−2	14	10	5	10	10	7	8	11	8	18	18	15	134	18·3
−3	2	1	2	1	3	1	2	1	5	1	1	4	24	3·3
−4	1		1				1					1	4	0·5

*East Park values minus Weather Centre values. The 24-hour period starts and ends at 0900 GMT.

It will be seen that on 30·6 per cent of the days the daily difference between the sites lay between +0·5 and −0·5 degF (Marshall[1]: 13·7 per cent). Roof minimum temperatures more than 0·5 degF below those at the park occurred on 3·4 per cent of occasions (Marshall: 3·6 per cent).

Of the remaining 65·9 per cent of the days (482 days) with roof minimum temperatures higher than in the park, only 3·8 per cent (28 days) showed differences greater than 2·5 degF (Marshall: 37·1 per cent), the largest of which were between 3·5 and 4·5 degF (four occasions) and were fairly evenly distributed throughout the year.

Discussion.—The closer agreement between the two sites in Southampton than between those in London is probably mainly due to the lower height of the building above street level (33 ft against 122 ft) and the lower thermal capacity of the smaller building.

It is possible, too, that in the newer building the heat insulation provided by the ventilated vermiculite may have had some influence on the results.

About 88 per cent of the roof maxima fell within the range 0·5 degF above to 2·5 degF below the Park maxima, and nearly 93 per cent of the roof minima fell within the range 0·5 degF below to 2·5 degF above the Park values. It would appear, therefore, that no misleading conclusions would be conveyed by comparison of extreme temperatures recorded on the roof site with the appropriate official climatological mean or extreme. Neither does it seem unreasonable to assume that, at times of day other than when the extremes occurred, the temperatures would not show any greater variation between the conventional and unconventional exposures.

REFERENCE

1. MARSHALL, W. A. L.; London temperatures. *Met. Mag., London*, **77**, 1948, p. 54.

551.501.45:551.524.33(420)

PERSISTENCE IN MONTHLY MEAN TEMPERATURE IN CENTRAL ENGLAND

By R. MURRAY

Summary.—Central England monthly temperatures in quintiles, derived from anomalies from 25-year moving averages over the period 1873–1963, are analysed into runs of 1, 2, 3, etc., months of similar temperature type. The factual information on these runs is presented in tables, and certain persistence relationships of predictive value are noted.

Introduction.—It is well known that persistence on various time scales is an important feature of surface temperature. Indeed the strength of temperature persistence from one month to another at numerous places in and near Europe has been assessed by Craddock and Ward.[1] In particular, they showed that persistence is notably strong in winter (December to March) and summer (June to September) months in central England. Although persistence relationships are not generally a satisfactory basis for long-range forecasting, they must at least be borne in mind when considering the many relevant factors. Experience suggests that runs of similar months show strongly persistent characteristics, and it seemed worth-while to find out whether relationships of predictive value would emerge from an examination of sequences of months of similar type.

The temperatures given by Manley[2] for central England were recently made available by Craddock in the form of monthly anomalies from the averages of the preceding 25 months of the same name. These anomalies were ranked and grouped into five equal classes (quintiles) for the 90 years from December 1873 to November 1963. The quintile boundaries are shown in Table I. When monthly anomalies are taken from the long-period mean temperatures (i.e. 90-year averages) there is a tendency for anomalies of the same sign in certain seasons to cluster around certain periods; for example, positive anomalies occurred more frequently in winter months during the first 40 years of the 20th century than in the periods 1873–99 and 1940–63. By taking anomalies from moving averages the effects of longer-period secular changes are lessened. Moving averages over a 25-year period appear to eliminate most of the climatic change in the 90 years; at the same time means over 25 years are not much affected by large year-to-year variations. Thus the choice of 25 years for the period of the averaging is arbitrary but appears reasonable in practice.

TABLE I—QUINTILE BOUNDARIES OF CENTRAL ENGLAND MONTHLY MEAN TEMPERATURE ANOMALIES BASED ON DEPARTURES FROM 25-YEAR RUNNING MEANS FOR THE PERIOD DECEMBER 1873 TO NOVEMBER 1963 AND ALSO MEAN TEMPERATURES FOR THE 25-YEAR PERIOD 1942–66

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
							degrees	*Celsius*					
5/4	≥	+1·5	+1·5	+1.5	+1·2	+1·1	+0·9	+1·2	+1·0	+1·1	+1·1	+1·4	+1·4
4/3	≥	+0·5	+0·8	+0·5	+0·4	+0·3	+0·3	+0·3	+0·3	+0·4	+0·8	+0·7	+0·8
3/2	≥	0·0	−0·4	−0·3	−0·2	−0·2	−0·1	−0·4	−0·2	−0·2	0·0	+0·1	−0·1
2/1	≥	−1·2	−1·5	−1·2	−1·0	−0·9	−0·7	−0·9	−1·0	−0·9	−0·9	−0·9	−1·4
Mean temperature		3·2	3·8	5·8	8·7	11·6	14·4	16·0	15·7	13·7	10·4	6·6	4·5

Note. For example, the quintile is 4 in a particular January if the temperature anomaly is equal to or greater than +0·5 degC and less than +1·5 degC; the anomaly is derived from the average of the 25 January temperatures immediately before the particular January.

The 1080 months from December 1873 to November 1963 were classified in quintiles and analysed by computer for runs of various types. For this purpose 12 types were taken, namely types T_1, T_2, T_3, T_4, T_5, $T_{1,2}$, $T_{2,3}$, $T_{3,4}$, $T_{4,5}$, $T_{1,2,3}$, $T_{2,3,4}$ and $T_{3,4,5}$. T_1 refers to runs of months of quintile 1; $T_{1,2}$ refers to runs in which each month is quintile 1 or quintile 2; $T_{1,2,3}$ refers to runs of quintiles 1 or 2 or 3, and so on.

The frequencies of runs characterized by each of the 12 types were calculated irrespective of the month on which the runs began and also according to the starting month. Since seasonal differences in the strength of persistence are a real feature,[1] it is reasonable to expect that the probabilities of runs of a particular type lasting another month should depend on the month on which the run starts and on the length of the run. Analysis of the runs in this way unearthed some facts of general interest as well as being of some practical use. In this note a January run means a run which starts in January; a January to February run means a run which starts in January and is still in existence in February; and so on.

Runs specified by one quintile.—The frequencies of runs characterized by temperature quintile 1 (i.e. T_1 type) were calculated irrespective of the month on which the runs began and also according to the starting month.

Taking no account of the starting month, the actual frequencies of type T_1 runs of exactly one, exactly two, etc., months were compared with the frequencies expected from a geometrical distribution in which the statistical parameters are climatological probability (i.e. probability $p = 0{\cdot}2$ in this case) and the number of runs of at least one month.[3] Similar statistical computations were carried out for types T_2, T_3, T_4 and T_5. Table II presents the comparisons between observed (O) and climatological (C) frequencies.

TABLE II—OBSERVED FREQUENCIES (O) OF RUNS OF 1, 2, 3, ETC., MONTHS COMPARED WITH FREQUENCIES (C) EXPECTED FROM THE CLIMATOLOGICAL PROBABILITY

Months		1	2	3	4	≥5
T_1	O	99	26	8	6	4
	C	114·4	22·9	4·6	0·9	0·2
T_2	O	121	29	4	6	0
	C	128·0	25·6	5·1	1·0	0·3
T_3	O	142	26	5	0	2
	C	140·0	28·0	5·6	1·1	0·3
T_4	O	132	21	8	2	1
	C	131·2	26·2	5·2	1·0	0·3
T_5	O	115	25	9	5	0
	C	123·2	24·6	4·9	1·0	0·2

Table II shows that occurrences of single months of T_1 are fewer and runs of two, three, etc., months of T_1 are generally more frequent than might be expected on the assumption that the probability of a T_1 month is independent of the preceding month (i.e. $p \simeq 0{\cdot}2$). At the opposite extreme (T_5 case) the occurrences of single months are fewer, and runs of three or four months are more frequent than climatological expectations. Chi-square tests confirm that the differences between the O and C frequencies for the extreme categories (i.e. T_1 and T_5 cases) are highly significant. In the T_4 case the differences between the O and C frequencies are significant, largely because there is a deficiency of O relative to C at two months and a relative excess at three or more months. In the T_2 and T_3 types there is no statistically significant difference between the O and C distributions.

A breakdown of the runs of single type according to the starting month is shown in Table III for the two extreme categories.

Because of the inadequate data and the insufficiently high probability of persistence, it is evident that few useful results emerge from the breakdown of the runs in Table III. However, it is worth noting the rather strong persistence from January, from February and from March to the following month in the T_1 type, and from June to July in T_5. The lack of persistence from April to May and from September to October in T_5 is also noteworthy.

The results from a breakdown of the T_2, T_3 and T_4 categories are not shown. The strongest persistence appears to be from January to February in T_4 (6/12 meaning that 6 persisted in 12). No persistence (or anti-persistence) is indicated for T_2 runs starting in June (0/11), for T_3 runs starting in February

TABLE III—FREQUENCIES OF RUNS OF AT LEAST 1, 2, 3, ETC., MONTHS OF T^1 (MUCH BELOW AVERAGE) AND T_5 (MUCH ABOVE AVERAGE) TYPES BEGINNING IN SPECIFIED MONTHS

Starting month	Runs equal to or greater than specified lengths in months							
	T_1				T_5			
	1	2	3	4	1	2	3	4
Jan.	12	5	0	0	15	2	2	0
Feb.	10	4	1	0	15	5	3	1
Mar.	12	4	3	0	13	5	2	2
Apr.	13	3	1	1	9	1	0	0
May	11	3	1	1	14	5	0	0
June	15	4	2	2	11	6	2	1
July	13	4	1	1	12	4	2	1
Aug.	11	3	2	0	12	3	1	0
Sept.	10	3	2	1	11	1	0	0
Oct.	12	4	1	1	13	2	0	0
Nov.	11	3	2	1	14	2	0	0
Dec.	13	4	2	2	15	3	2	0

(1/14) or May (1/13) or November (1/16) and for T_4 runs starting in February (1/8) or June (1/14). These results are perhaps of little practical use in view of the fact that there is only a 20 per cent chance of occurrence of any single type on the assumption that there is no persistence from month to month.

Runs specified by two adjacent quintiles.—As in the preceding section, calculations and comparisons were carried out for the $T_{1,2}$, $T_{2,3}$, $T_{3,4}$ and $T_{4,5}$ types. It should be understood that, say, a $T_{2,3}$ run may be of any length provided that each month is quintile 2 or 3 but not 1, 4 or 5. Table IV contains data for the cases taken irrespective of the name of the starting month. In this category the climatological probability is 0·4 approximately.

TABLE IV—OBSERVED FREQUENCIES (O) OF RUNS OF 1, 2, 3, ETC., MONTHS COMPARED WITH FREQUENCIES (C) EXPECTED FROM THE CLIMATOLOGICAL PROBABILITY

Months		1	2	3	4	5	6	⩾7
$T_{1,2}$	O	116	42	21	16	9	3	5
	C	127·2	50·9	20·4	8·1	3·3	1·3	0·8
$T_{2,3}$	O	151	52	26	12	7	1	2
	C	150·6	60·2	24·1	9·6	3·9	1·5	1·0
$T_{3,4}$	O	147	58	24	9	4	1	4
	C	148·2	59·3	23·7	9·5	3·8	1·5	1·0
$T_{4,5}$	O	128	47	18	14	7	3	5
	C	133·2	53·3	21·3	8·5	3·4	1·4	0·9

The differences between the O and C frequencies are greatest for the two extreme categories ($T_{1,2}$ and $T_{4,5}$); chi-square tests confirm that the differences are highly significant. When temperatures are nearer normal ($T_{2,3}$ and $T_{3,4}$ cases) persistence appears to be generally much less, and indeed chi-square tests failed to show any statistically significant differences between the O and C frequencies for these two types. However, it should not be concluded that there is no persistence in all seasons for the $T_{2,3}$ and $T_{3,4}$ categories, since no account has been taken of the starting month in Table IV.

In Table V the observed frequencies are shown when account is in fact taken of the month in which runs begin.

TABLE V—FREQUENCIES OF RUNS OF AT LEAST 1, 2, 3, ETC., MONTHS OF $T_{1,2}$, $T_{2,3}$, $T_{3,4}$ AND $T_{4,5}$ TYPES BEGINNING IN SPECIFIED MONTHS

Starting month	Runs equal to or greater than specified lengths in months											
	1	2	3	4	5	6	1	2	3	4	5	6
			$T_{1,2}$						$T_{2,3}$			
Jan.	18	9	5	2	0	0	20	9	6	2	2	0
Feb.	14	6	2	1	0	0	21	7	3	1	1	1
Mar.	15	8	6	4	2	1	20	8	4	1	1	0
Apr.	18	4	1	1	0	0	20	10	3	1	0	0
May	20	11	3	3	1	0	19	6	5	2	0	0
June	19	11	8	5	3	1	23	7	2	2	1	0
July	19	7	4	2	0	0	20	9	5	4	1	0
Aug.	16	9	6	2	1	0	23	9	5	1	1	0
Sept.	14	6	6	4	3	1	21	6	2	1	0	0
Oct.	19	6	0	0	0	0	22	14	7	4	2	1
Nov.	19	8	4	4	3	2	20	7	4	3	1	1
Dec.	21	11	9	5	4	3	22	8	2	0	0	0
			$T_{3,4}$						$T_{4,5}$			
Jan.	20	9	4	4	1	1	19	6	3	1	0	0
Feb.	17	5	3	1	1	1	17	10	6	2	1	1
Mar.	23	8	1	1	1	1	17	9	5	4	4	3
Apr.	19	12	3	1	0	0	17	6	4	2	2	1
May	20	8	4	2	2	1	21	5	1	1	1	0
June	20	8	2	1	1	1	21	11	5	2	1	0
July	20	7	3	1	0	0	17	8	3	0	0	0
Aug.	23	8	4	2	1	0	16	10	5	4	1	1
Sept.	22	11	6	1	0	0	17	7	3	2	0	0
Oct.	18	8	4	2	1	0	17	4	2	2	2	0
Nov.	20	6	2	0	0	0	22	8	3	2	0	0
Dec.	25	10	6	2	1	0	21	10	7	7	3	2

Table V contains a good deal of interesting information, and some noteworthy features are summarized below.

(i) $T_{1,2}$ — December to January runs show strong persistence to February (9/11).

(ii) $T_{1,2}$ — April runs have anti-persistence to May (4/18) or June (1/4), but March to April runs show persistence to May (6/8).

(iii) $T_{1,2}$ — July runs show little persistence to August (7/19), but June to July runs are persistent to August (8/11).

(iv) $T_{1,2}$ — October runs have little or no persistence to November (6/19) or December (0/6), but September to October runs appear to persist to November (6/6).

(v) $T_{2,3}$ — June runs show little or no persistence to July (7/23), but May to June runs show persistence to July (5/6).

(vi) $T_{2,3}$ — September runs show little persistence to October (6/21), but runs of two or more months show some persistence to October (10/16).

(vii) $T_{3,4}$ — April runs show some persistence to May (12/19) but no long persistence.

(viii) $T_{4,5}$ — February runs show rather weak persistence to March (10/17), but December to February runs are probably strongly persistent to March (7/7).

(ix) $T_{4,5}$ — May runs are non-persistent to June (5/21), but March to May runs show some persistence to June (4/5).

Runs specified by three adjacent quintiles.—The types under consideration in this section are $T_{1,2,3}$, $T_{2,3,4}$ and $T_{3,4,5}$. A $T_{2,3,4}$ run starts with quintile 2 or 3 or 4 (thus it is preceded by quintile 1 or 5), and each month must be quintile 2 or 3 or 4. Table VI presents the data for all cases (i.e. irrespective of month on which run starts). Here the climatological probability is 0·6 approximately.

TABLE VI—OBSERVED FREQUENCIES (O) OF RUNS OF 1, 2, 3, ETC., MONTHS COMPARED WITH FREQUENCIES (C) EXPECTED FROM THE CLIMATOLOGICAL PROBABILITY

Months		1	2	3	4	5	6	≥7
$T_{1,2,3}$	O	80	47	36	22	11	10	16
	C	88·8	53·3	32.0	19.2	11·5	6·9	10·2
$T_{2,3,4}$	O	93	57	34	20	18	12	12
	C	98·4	59·0	35·4	21·3	12.8	7·7	11·4
$T_{3,4,5}$	O	81	45	25	20	13	7	21
	C	84·8	50·9	30·5	18·3	11·0	6·6	9·9

In this case chi-square tests indicate that there is a statistically significant difference between the O and C frequencies in the $T_{3,4,5}$ category but not in the other two cases. The coarsening of the criteria by introducing quintile 3 into each category appears to result in the O and C frequencies in the colder ($T_{1,2,3}$) of the two extreme categories being statistically indistinguishable from each other. This does not, however, mean that observed runs at certain times of the year are necessarily independent of the temperature type before the run commences. It is entirely reasonable to suppose that strong persistence in runs beginning at particular months might be largely counterbalanced by non-persistence or anti-persistence in runs which start in different months, thus resulting in the non-significance of the differences between the O and C frequencies in the $T_{1,2,3}$ and $T_{2,3,4}$ cases.

In Table VII are presented the frequencies when account is taken of the month on which runs start.

Examination of the data in Table VII suggests the following features of temperature persistence.

(i) $T_{1,2,3}$ — Persistence to January is strongest for spells of 3 to 6 months (16/20); there is little or no persistence for shorter spells.

(ii) $T_{1,2,3}$ — January runs show persistence to February (14/18) and January to February runs tend to persist to March (10/14).

(iii) $T_{1,2,3}$ — Runs which begin in June or July and continue to August usually persist to September (18/23), but in August runs are non-persistent to September (9/17).

(iv) $T_{1,2,3}$ — September runs are non-persistent (or anti-persistent) to October (7/16), but August to September runs are strongly persistent to October (8/9), whilst July to September and June to September runs also show persistence to October.

(v) $T_{2,3,4}$ — Runs which begin in October or November and exist to January persist to February (11/13) — in other words, it is probable that February will not be an extreme month if October to January or November to January do not contain extreme months.

(vi) $T_{2,3,4}$ — March and February to March runs show no persistence to April, but persistence to April (15/18) is strong if the run is at least three months old prior to April.

(vii) $T_{2,3,4}$ — March to May runs exhibit persistence to June (7/8) and July (6/7).

(viii) $T_{2,3,4}$ — Whilst June runs show little persistence to July (11/19), May to June runs usually persist to July (9/11).

(ix) $T_{3,4,5}$ — December to January runs are persistent to February (14/15), March ((11/14) and April (8/11).

(x) $T_{3,4,5}$ — Runs which start in January or February or March and exist in May generally persist to June (10/11).

(xi) $T_{3,4,5}$ — Runs which have lasted for at least four months prior to August usually persist to August (15/17), but shorter runs show only weak persistence.

TABLE VII—FREQUENCIES OF RUNS OF AT LEAST 1, 2, 3, ETC., MONTHS OF $T_{1,2,3}$, $T_{2,3,4}$ AND $T_{3,4,5}$ TYPES BEGINNING IN SPECIFIED MONTHS

Starting month	Runs equal to or greater than specified lengths in months											
	1	2	3	4	5	6	7	8	9	10	11	12
						$T_{1,2,3}$						
Jan.	18	14	10	6	1	1	1	1	1	0	0	0
Feb.	17	10	6	3	3	2	1	1	1	1	1	1
Mar.	15	9	6	3	2	2	1	1	1	1	0	0
Apr.	18	11	5	3	2	1	1	1	0	0	0	0
May	21	15	8	5	3	2	0	0	0	0	0	0
June	21	16	11	8	6	3	1	0	0	0	0	0
July	17	12	10	6	1	1	1	1	1	1	1	1
Aug.	17	9	8	6	5	4	3	3	3	2	2	2
Sept.	16	7	5	3	3	1	1	1	1	1	1	1
Oct.	21	15	11	8	6	4	4	3	1	0	0	0
Nov.	20	11	6	3	3	3	2	1	1	1	1	1
Dec.	21	13	9	5	2	2	0	0	0	0	0	0
						$T_{2,3,4}$						
Jan.	23	14	9	7	5	1	0	0	0	0	0	0
Feb.	20	12	6	4	3	3	0	0	0	0	0	0
Mar.	22	12	8	7	6	4	2	1	0	0	0	0
Apr.	21	15	9	3	2	1	1	0	0	0	0	0
May	18	11	9	6	3	2	2	2	1	1	1	1
June	19	11	5	2	1	0	0	0	0	0	0	0
July	20	12	9	7	6	3	1	1	0	0	0	0
Aug.	23	16	9	5	3	2	0	0	0	0	0	0
Sept.	22	16	11	6	3	1	0	0	0	0	0	0
Oct.	18	14	9	6	5	2	2	0	0	0	0	0
Nov.	18	10	7	6	3	3	2	0	0	0	0	0
Dec.	22	10	5	3	2	2	2	1	1	1	0	0
						$T_{3,4,5}$						
Jan.	16	8	6	5	1	1	1	1	1	1	0	0
Feb.	14	8	5	5	5	5	5	5	4	2	2	1
Mar.	17	9	5	4	1	1	0	0	0	0	0	0
Apr.	16	11	6	6	5	4	4	2	2	2	2	2
May	21	11	5	2	2	0	0	0	0	0	0	0
June	18	12	8	5	2	2	1	1	1	1	1	1
July	19	12	8	5	3	1	1	1	1	1	0	0
Aug.	17	12	6	5	3	2	2	2	1	0	0	0
Sept.	15	11	8	5	3	2	0	0	0	0	0	0
Oct.	16	10	7	4	4	2	0	0	0	0	0	0
Nov.	21	12	8	4	4	4	4	3	2	1	1	1
Dec.	22	15	14	11	8	4	3	2	2	2	2	1

General remarks.—The main purpose of the analysis in this article is not so much to confirm the reality of temperature persistence on the monthly time scale but to present the facts concerning runs of months in as useful a practical form as possible.

The list of noteworthy features contains apparent associations based on quite small samples (most have less than 20 and some less than 10 cases), and it is evidently not always possible to present evidence of their statistical significance.

The validity of many of the 'rules' rests for the most part with their reasonableness in relation to synoptic experience. It appears that runs of two or more months with similar temperature characteristics tend to occur in winter to early spring and in the summer, whilst the non-persistent periods tend to be about late spring or early summer and late autumn. These seasonal maxima and minima of temperature persistence are broadly in line with the maxima and minima of long synoptic spells as put forward by Lamb,[4] although it is not to be expected that there should be a very close relationship. Furthermore, it is an empirical fact that the general circulation appears to have 'moods' in which persistence or repeated re-appearance of similar broad-scale types characterizes a season or more. These are not understood, but they may be related in a complex manner to quasi-persistent, anomalous sources of energy from the sea.[5] In view of the interruptions in circulation type which commonly occur within a long period of broadly similar characteristics, it is not surprising that runs involving two or three adjacent quintiles (e.g. $T_{1,2}$, $T_{3,4,5}$) are involved in the persistence relationships presented in this note.

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SOME COMPARISONS BETWEEN TEMPERATURES FROM MOORLAND STATIONS AND CORRESPONDING RADIOSONDE TEMPERATURES

By B. INGHAM

Introduction.—It was noticed in the summers of 1960 and 1961 that afternoon temperatures reported on sunny days by Lowther Hill and Snaefell were often much higher than the 1200 GMT temperatures obtained by radiosonde for a corresponding level in the free atmosphere. In 1962 a preliminary

study was made of the differences between moorland station temperatures and radiosonde temperatures, and further comparisons have now been made using 1964–66 data.

Data used in the comparisons.—The moorland stations used were Lowther Hill, Great Dun Fell and Snaefell and the radiosonde stations were Long Kesh, Shanwell and Aughton (Figure 1).

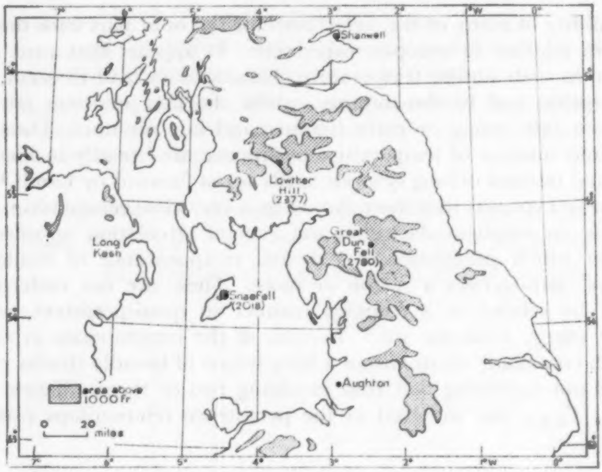

FIGURE 1—MAP SHOWING THE RELATIVE POSITIONS OF THE STATIONS
Figures in brackets indicate the altitudes of the observation points in feet.

Initially it was intended to use data obtained during settled spells of weather when there would probably not be large differences between the surrounding radiosonde stations. There was therefore some interdependence between data for days within a spell. Settled spells were few however, and extra observations were obtained by examining single days which appeared from the observations to have been sunny at some time and for which suitable radiosonde data were available. Use was also made of observations from Lowther Hill for every day in April 1962 and from Lowther Hill and Great Dun Fell for every day in May 1964. The Snaefell data could not be fully analysed because sunshine data and some maximum temperatures were not available.

The months examined varied from year to year but were between March and September and have loosely been described as summer months. The hours of sunshine for the selected days were tabulated along with 1200 GMT and maximum temperatures for the moorland stations. Radiosonde temperatures from the 1200 and 0000 GMT ascents from the radiosonde station most nearly upwind of the moorland station were also tabulated for heights 75, 85 and 100 mb above MSL for comparison with Snaefell, Lowther Hill and Great Dun Fell respectively. In a few cases where it was difficult to

decide the most appropriate ascent the mean of two or more ascents was used. When the flow was easterly it was often difficult to decide whether to use the ascent from Aughton or Shanwell. Very often the ascent from Shanwell was so much colder at the relevant levels that it seemed quite unreasonable to use it, yet the sequence of weather at the stations — normally hill fog until nearly midday followed by a clearance and a big rise in temperature — suggested that perhaps its use was justified in some of the cases.

Days were classified as days of light wind if the geostrophic wind was less than 15 kt at the time of maximum temperature. Days were classified as 'sunny' if there were 6·1 or more hours of sunshine — the lower limit of one of the statistical divisions for sunshine duration.

At Lowther Hill, out of 185 days examined, there were 95 sunny days of which 59 were light wind days; at Great Dun Fell, out of 116 days examined, there were 60 sunny days of which 37 were light wind days; at Snaefell, out of 82 days examined 32 days were chosen as 'sunny' with light wind after consideration of the cloud amount reports.

Results.—On the average, for all occasions examined, the 1200 GMT temperatures at all the moorland stations were over 1 degC higher than the corresponding radiosonde temperatures. Because of the method of selection of data these mean differences are not so useful as the mean differences given in Table I for 'sunny' days. The mean differences for 1200 GMT temperatures on sunny days were about 2 degC with light wind but less if the wind was

TABLE I—MEAN DIFFERENCES BETWEEN TEMPERATURES AT MOORLAND STATIONS AND TEMPERATURES IN THE FREE ATMOSPHERE

Station		Lowther Hill	Great Dun Fell	Snaefell
Height of observing point above MSL (ft/ mb)		2377/85	2780/100	2018/75
Period		1962, 1964–66	1964–66	1965–66
		degC	*degC*	*degC*
Sunny† with light‡ wind	$H_{12}-R_{12}$	2·6 ($58_{8·5}$)*	2·2 ($36_{5·5}$)	1·8 (32_{6})
	H_M-R_{12}	5·2 (59_{11})	4·0 ($37_{8·5}$)	3·7 ($32_{6·5}$)
	H_M-R_{24}	4·8 ($44_{10·5}$)	3·1 ($25_{7·5}$)	—
Sunny with more than light wind	$H_{12}-R_{12}$	1·1 ($36_{11·5}$)	1·8 (23_{8})	—
	H_M-R_{12}	3·7 ($36_{7·5}$)	3·4 (23_{7})	—
	H_M-R_{24}	3·7 (25_{12})	2·3 ($16_{10·5}$)	—

* In brackets beside the mean are given the number of occasions followed by a subscript giving the range between the lowest and highest differences.

† day with 6·1 or more hours of sunshine (sunshine estimated for Snaefell).

‡ Geostrophic wind less than 15 kt at time of maximum temperature.

H_{12} = Temperature at moorland station at 1200 GMT.

H_M = Maximum at moorland station.

R_{12} = Radiosonde temperature at level of moorland station from upwind ascent at 1200 GMT.

R_{24} = Radiosonde temperature at level of moorland station from upwind ascent at 0000 GMT. Comparison made on occasions when there was continuity of air mass from one day to the next.

stronger, especially at Lowther Hill. The moorland maximum exceeded the 1200 GMT radiosonde temperatures in light winds by as much as 4 or 5 degC on the average but did not exceed the 0000 GMT radiosonde temperatures by as much, though there was a good deal of variation (see Table I for range of variation). The inference, that the 0000 GMT radiosonde temperature at 85–100 mb above MSL was higher than that at 1200 GMT, is supported by monthly averages of temperatures at 900 mb being higher at 0200 GMT than at 1400 GMT for Larkhill/Crawley[1] and for Lerwick.[2] Presumably heating at 900 mb continues after 1200 GMT but cooling does not extend upwards to 900 mb in the free atmosphere until after midnight. (C. L. Hawson in a personal communication to the Editor remarks that the possibility that the effect is an instrumental one cannot yet be dismissed.)

Published data on the subject of the differences of temperature between the free air and mountain stations are scarce and to some extent conflicting. Russian authors say that mountain temperatures are about 3 degC warmer than the free air temperature in summer and about 2 degC colder when the ground is covered by ice or snow.[3] Hastenrath[4] says that the yearly average is about 3 degC warmer at about 3000 m on the high ground in central America than at corresponding radiosonde stations on the coast and in the Caribbean islands. Earlier comparisons made in Norway by Eide[5] showed that the free air is warmer, taking the year as a whole.

It is clear that there is a diurnal variation of temperature at hill stations, which may not be the same as that in the free atmosphere, and it is necessary to specify the time of day to which comparisons of temperature between hill stations and radiosondes refer. This has been omitted in some of the papers and it makes comparisons of results difficult. This paper shows that for three moorland stations in Britain above 2000 ft the temperature on sunny summer days at 1200 GMT with light winds is about 2 degC warmer than the corresponding temperature in the free atmosphere. A knowledge of these differences may be useful in assessing the likelihood of convective developments.

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551.501.81:551.551.25

MESO-SCALE WIND FLUCTUATIONS BELOW 1500 METRES

By T. W. HARROLD and K. A. BROWNING

Summary.—A pulsed Doppler radar has been used to investigate the space and time fluctuations of the longitudinal component of the horizontal wind in the lowest 1500 m during widespread precipitation. A much greater spatial density of observations was obtained compared with that from other wind measuring techniques. Below 300 m the wind fluctuations had a magnitude of about 1 m/s. Above 300 m they had a magnitude of several metres per second and were persistent for periods of minutes. Most of the persistent eddies were shallow (about 200 m) and moved with the wind at their level; they are believed to have been due to the breakdown of the vertical windshear. A few, however, were relatively deep (about 800 m) and travelled with a speed representative of the layer of melting snow.

Introduction.—Studies of wind variations above the surface boundary layer have been made by numerous workers using a variety of sensors — for example, anemometers on tall masts, balloons and aircraft. All of these provide a poor sample in space and, if the spatial structure of the wind field is required, data from different times have to be combined. It is then necessary to assume that the turbulence is 'frozen', variations moving across the observational point(s) without temporal change. In precipitation a much improved coverage of the spatial wind structure can be obtained using a pulsed Doppler radar to measure the radial velocity of the precipitation particles. When measurements are confined to low elevation angles the fallspeed of the precipitation can be neglected; the radar then effectively measures the component of the horizontal wind along the radar beam. By choosing the azimuth along or across the mean wind direction it is possible to measure either the longitudinal (u) or transverse (v) components of wind velocity. In this paper we present measurements of the u component of the wind in the lowest 1500 m on horizontal scales between about 150 m (determined by the radar sampled volume and therefore a function of range) and 10 km on an occasion of widespread precipitation. The melting level was within the layer scanned by the radar and some inferences are made about the meso-scale air motion in this region.

Data acquisition.— The radar used in this study was a 3·2-cm pulsed Doppler located at the Royal Radar Establishment, Pershore, Worcestershire (52° 8′ N 2° 2′ W). The display of this radar (Plate 1) is an intensity modulated range-velocity matrix. Range elements were at 140 m intervals and velocity elements were at 1 m/s intervals. The photograph, Plate 1, taken with the aerial at elevation 7·5°, shows this matrix, with precipitation echoes at all ranges. The mean velocity of the precipitation increases from 6 m/s close to the radar, to 21 m/s at maximum range.

A radar samples a volume, rather than a point in space, and variations of velocity within a volume defined by the beam width and range gate result in the spread of velocities observed at any given range in Plate 1. This velocity spread is a measure of the shear and turbulence within the sampled volume and has been used by Rogers and Tripp[1] to study turbulence in snow. In the present investigation, however, we confine our attention to fluctuations on scales larger than the sampled volume. The velocity corresponding to the intensity peak of the spectrum at a given range is assumed to be representative of the centre of the sampled volume. This velocity can be estimated to about ±0·25 m/s. Velocity perturbations of several metres

per second can be seen in Plate 1, especially between slant ranges 4 and 8 km, and it is these that form the main subject of this paper.

A feature of the Pershore radar particularly important in the present study was the high rate of data acquisition, a photograph such as Plate 1 being obtained every second. By elevating the aerial by about 1° between every other photograph a range–height–velocity (RHV) section such as that in Figure 1 was obtained once every 20 s. On this section each dot indicates the location of a wind measurement.

Observations on 20 February 1967.—The measurements of the longitudinal (u) component of the wind presented in this paper were made during a 20-min period centred on 1400 GMT. Observations with the Doppler aerial pointing vertically, and also with an AN/TPS–10 range – height radar, showed that the bright band was steady at 950 m ($\pm$50 m) for at least two hours. It was deduced from these observations that the precipitation was entirely of snow above 950 m and entirely of rain below 750 m.

Doppler observations with the aerial vertical showed that at the centre of the spectrum the fallspeed (w) was 5 m/s in rain and 1 m/s in snow. Assuming these overhead values to apply over the RHV sections, the contributions of the fallspeed ($w \sin E$), where E is the elevation, to the observed Doppler velocity are as shown in Figure 1. The largest value, 1 m/s, occurs at $E = 11°$ in rain. Fluctuations about these values during the 20-min observation period are unlikely to have exceeded $\pm$20 per cent.

Wind speed and direction were measured immediately before and after the range – height scans by rotating the Doppler aerial in azimuth with the elevation constant at 20°. The variation of the observed velocity with azimuth is then sinusoidal, the peak corresponding to the wind direction.[2] The wind directions obtained in this manner are shown on the left of Figure 1. Evidently the changes over the 20-min period were negligible. An azimuth of 242° was used in the range – height scans. This was along the direction of the wind in the melting layer and at an angle of 20° to the wind at 200 m.

Figure 2 is an example of one of a total of forty consecutive RHV sections; it is taken from the middle of the observational period at a time corresponding to Plate 1. The velocities are uncorrected for precipitation fallspeed, and the values of $w \sin E$ in Figure 1 must be subtracted to obtain the horizontal wind, u. However, velocity fluctuations at any given level in Figure 2 can be attributed almost entirely to changes in u, fluctuations in $w \sin E$ being at most $\pm$0·2 m/s and mainly less than 0·1 m/s. Therefore the undulations of the velocity isopleths correspond to gusts and lulls.

The life history of gusts and lulls at any given height is conveniently depicted on distance–time sections such as that in Figure 3, due allowance being made for the time change over each RHV section. (For simplicity only the middle period of the complete record is shown.) This figure is a representation of the record of the u component that would have been obtained from a line of anemometers at a height of 600 m along azimuth 242°. The gusts and lulls are displayed as velocity spines, the more prominent gusts being emphasized by dashed lines in the figure. The gusts aa and bb in Figure 2 can be followed throughout Figure 3 but often the spines are less persistent than these. The speed of movement of a gust is given by the spine

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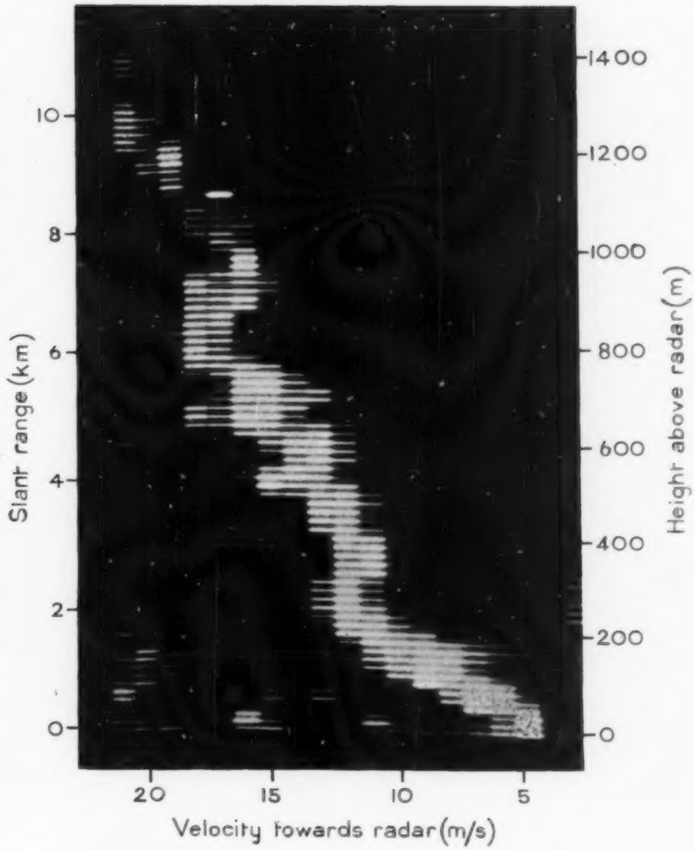

PLATE I—RANGE-VELOCITY DISPLAY

Observation made at 14 h 00 min 34 s on 20 February 1967 with elevation of 7·5° (see page 367).

Photograph by courtesy of the Norfolk Camera Centre

PLATE II—FROZEN SEA OVER THE SAND AT HUNSTANTON DURING LATE JANUARY 1963
(See page 381).

PLATE III—VERTICAL GUSTMETER (INCOMPLETE) BEING INSTALLED ON A RETRACTABLE BOOM AT THE 1252-FT LEVEL ON THE 1265-FT TELEVISION MAST

The housing for the wet-bulb and dry-bulb thermometers can be seen on the right of the picture, with the water supply for the wet-bulb thermometer. (See page 380.)

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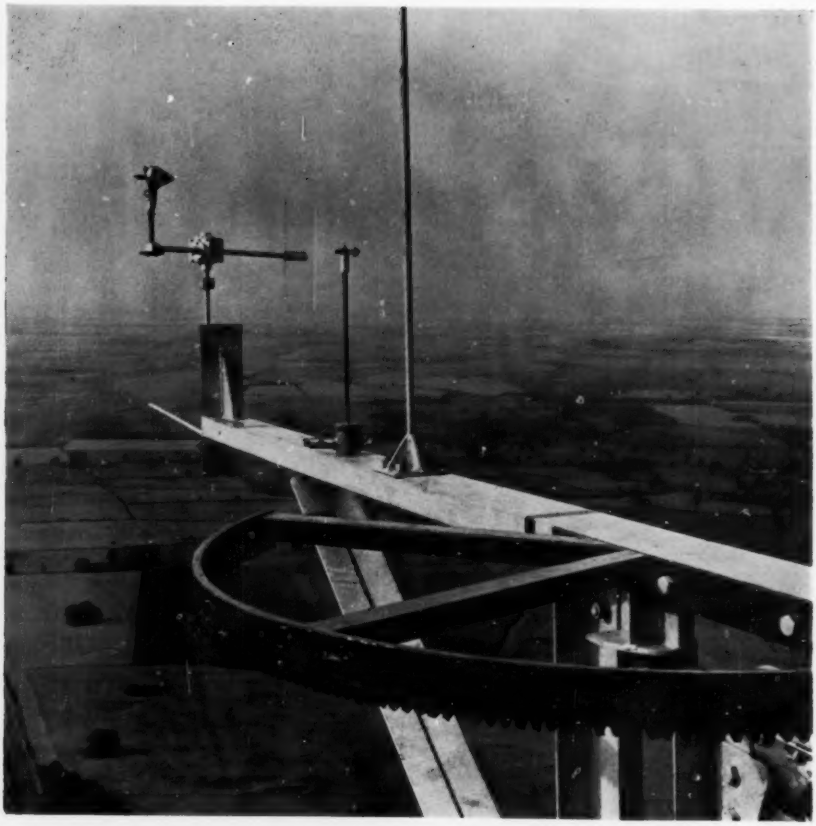

PLATE IV—VERTICAL GUSTMETER (INCOMPLETE) AND STAND FOR HORIZONTAL GUSTMETER ON A RETRACTABLE BOOM AT THE 1252-FT LEVEL ON THE 1265-FT TELEVISION MAST

(See page 380.)

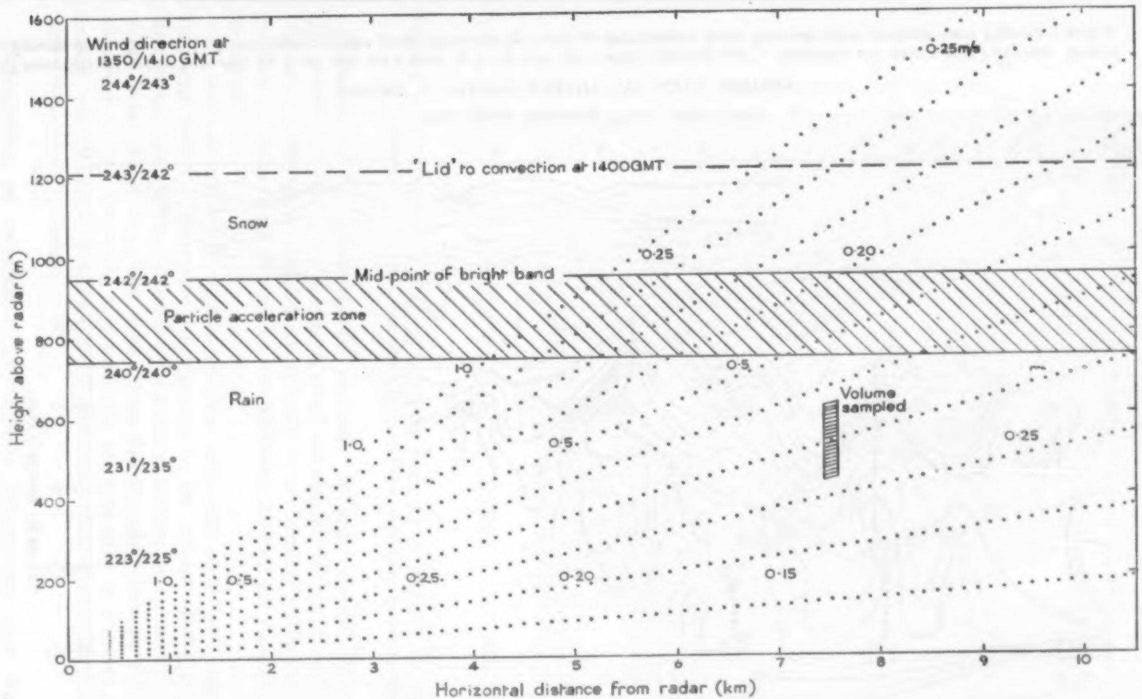

FIGURE 1—DENSITY OF DATA POINTS OBTAINED DURING ONE 20-SECOND RANGE-HEIGHT SCAN

Each dot corresponds to the centre of a range element, observations being at intervals of 1° in elevation. Also shown are the position of the radar bright band and the height interval where melting was occurring at 1400 GMT on 20 February 1967, some spot values of the component of the precipitation fallspeed towards the radar and, at the left-hand edge, the wind direction immediately before and after the observations discussed in this paper.

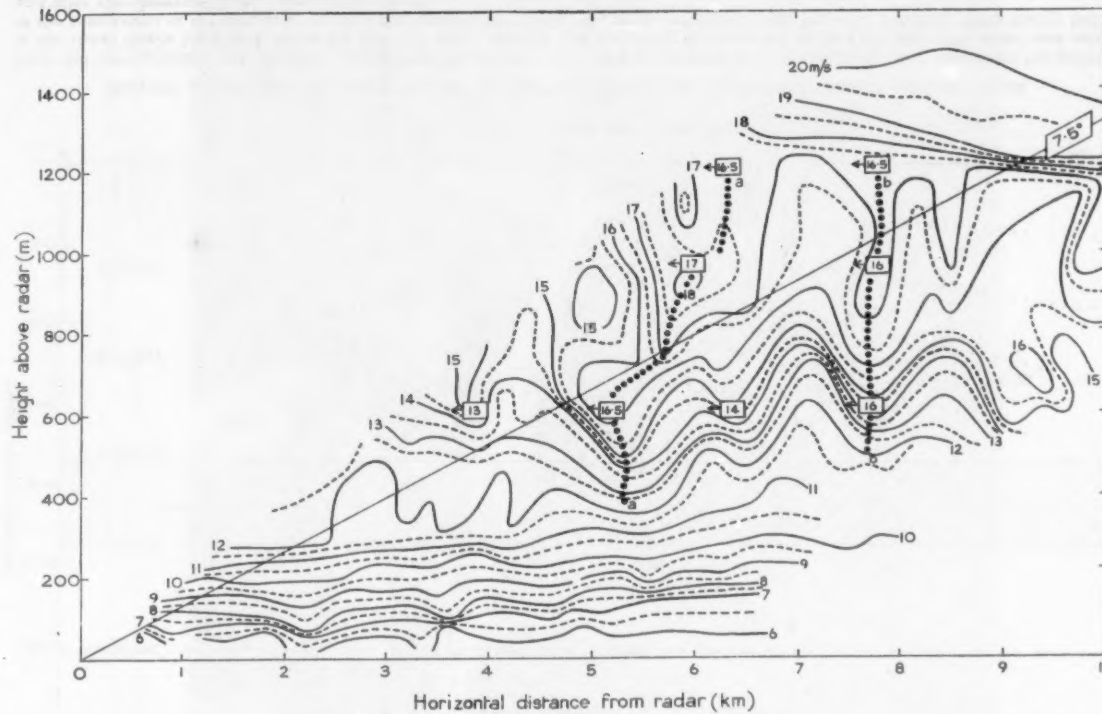

FIGURE 2—RANGE–HEIGHT–VELOCITY SECTION

Observations made between 14 h 00 min 20 s and 14 h 00 min 40 s with azimuth 242°. Isopleths are at 0·5 m/s intervals. Boxed figures show the speed of movement of the gusts (denoted by dots) as determined from distance–time sections—see Figures 3 and 4.

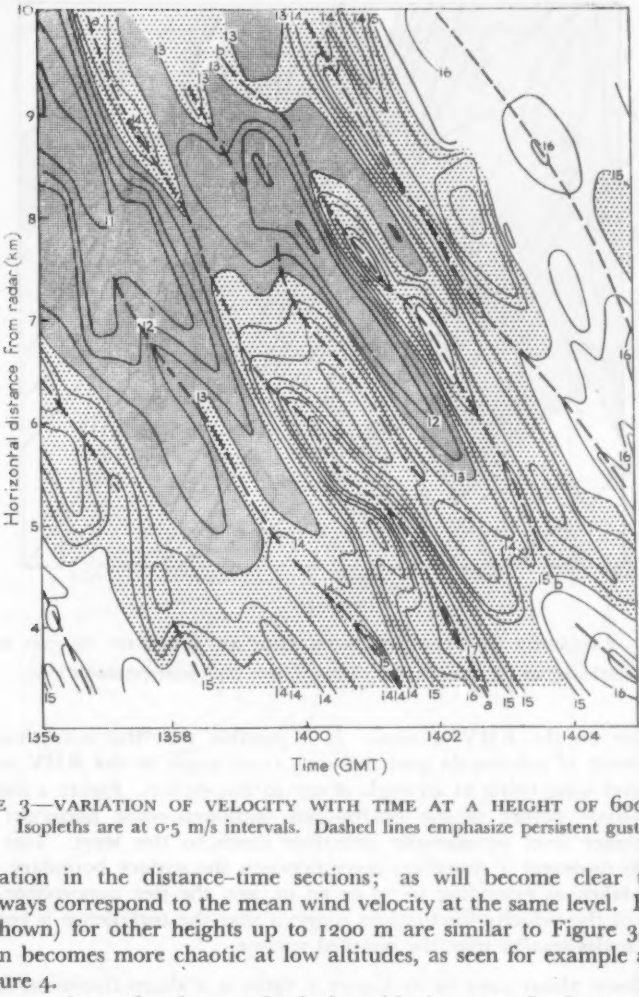

FIGURE 3—VARIATION OF VELOCITY WITH TIME AT A HEIGHT OF 600 METRES
Isopleths are at 0·5 m/s intervals. Dashed lines emphasize persistent gusts.

orientation in the distance–time sections; as will become clear this does not always correspond to the mean wind velocity at the same level. Diagrams (not shown) for other heights up to 1200 m are similar to Figure 3, but the pattern becomes more chaotic at low altitudes, as seen for example at 300 m in Figure 4.

Figure 5 shows the change of velocity with time at a fixed range of 7 km from the radar. The figure corresponds to the record of the *u* component that would have been obtained by a series of anemometers on a 1400-m mast 7 km from the radar. The figure was drawn using the 40 RHV sections obtained at 30-s intervals, together with sections such as Figures 4 and 5 to enable interpolations between RHV sections. Only fluctuations of duration more than 15 s are shown.

Discussion of results.—The velocity fluctuations may be classified according to their altitude :

(i) Below about 300 m velocity fluctuations of order 1 m/s occur at any given height. They are non-persistent, being identifiable typically for about

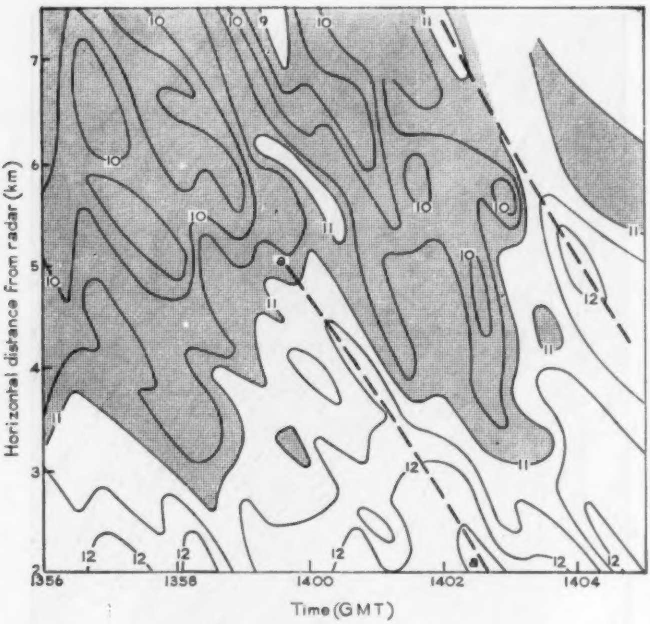

FIGURE 4—VARIATION OF VELOCITY WITH TIME AT A HEIGHT OF 300 METRES

Isopleths are at 0·5 m/s intervals. Dashed lines emphasize persistent gusts.

one minute on the RHV sections. It is possible that this non-persistence was the result of small-scale gusts moving at an angle to the RHV section, the low level wind being at an angle of 20° to this section. Figure 4 indicates the short-lived nature of the fluctuations, although some persistent gusts from a higher level occasionally penetrate down to this level. This layer appears to represent a transition layer between the surface boundary layer, generally taken as extending to 20 or 30 m, and the free atmosphere. The smallness of the velocity fluctuations suggests that the turbulence is confined mostly to scales smaller than the sampled volume.

(ii) Above about 1200 m in Figure 2 there is a sharp transition from a region of marked velocity fluctuations to one of relatively smooth flow, the 'lid' to the fluctuations coinciding approximately with the 18 m/s isopleth. The 'lid' is also clearly seen in Figure 5, where it lowers with time at a rate of 40 m/min. This 'lid' roughly coincides with the base of a weak frontal zone, although its rate of descent at this time is faster than that of the front on the synoptic scale.

(iii) Between about 300 m and the 'lid', velocity variations of several metres per second occur at any given height and individual features persist over several minutes. Figure 2 shows pronounced undulations in the velocity isopleths. The velocity fluctuations in this layer form the subject of the remainder of this section.

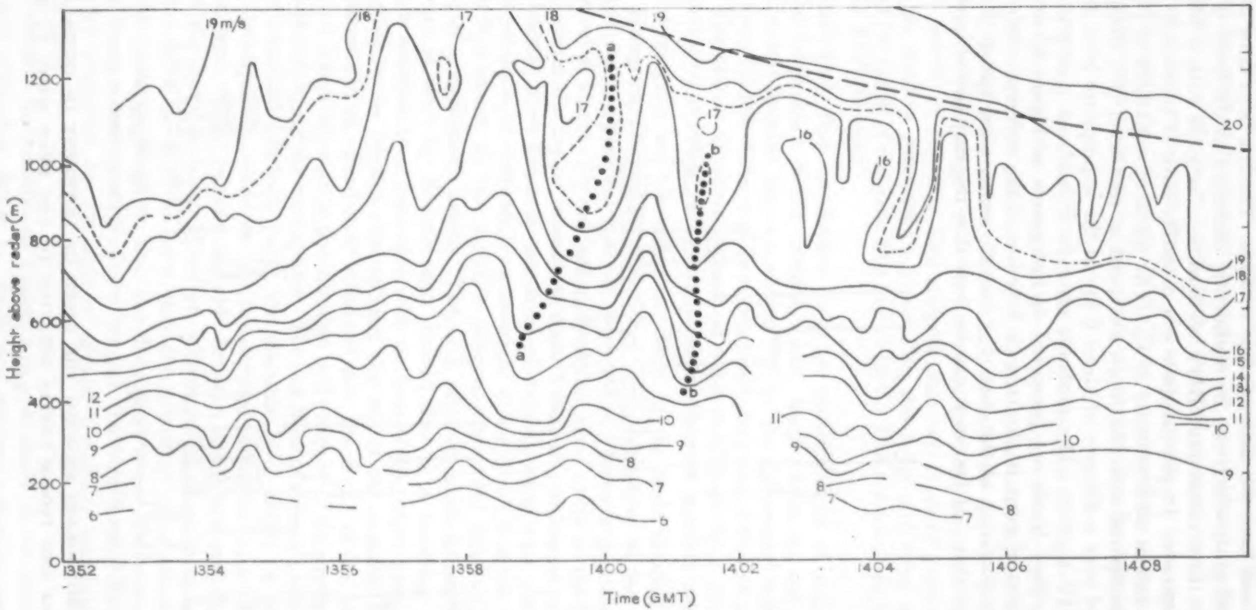

FIGURE 5—HEIGHT–TIME VARIATIONS OF VELOCITY AT A FIXED RANGE OF 7 KILOMETRES FROM THE RADAR

. . . . Persistent gusts — — — Lid to convection

Since the gusts are persistent in time their speed of movement (V_g) can be determined from the distance–time sections. This has been done at several levels for all gusts which can be confidently identified at the level of interest on at least three consecutive RHV sections, i.e. for gusts with a lifetime of at least a minute. In general there is a probable error of between $\pm$ 0·5 m/s and $\pm$1·0 m/s in each estimate of V_g. The speed of movement of each gust was then compared with the mean air speed at that level ($\bar{V}$), defined as a mean speed over a distance of about 6 km at the appropriate level and time on the RHV sections. The probable error in $\bar{V}$ is about $\pm$0·25 m/s. The results for three levels are presented as histograms in Figure 6, where the total duration of gusts is plotted as a function of the difference between the speed of propagation of the gust (V_g) and the mean wind speed ($\bar{V}$) at the level in question. At 600 m it can be seen that the majority of gusts move

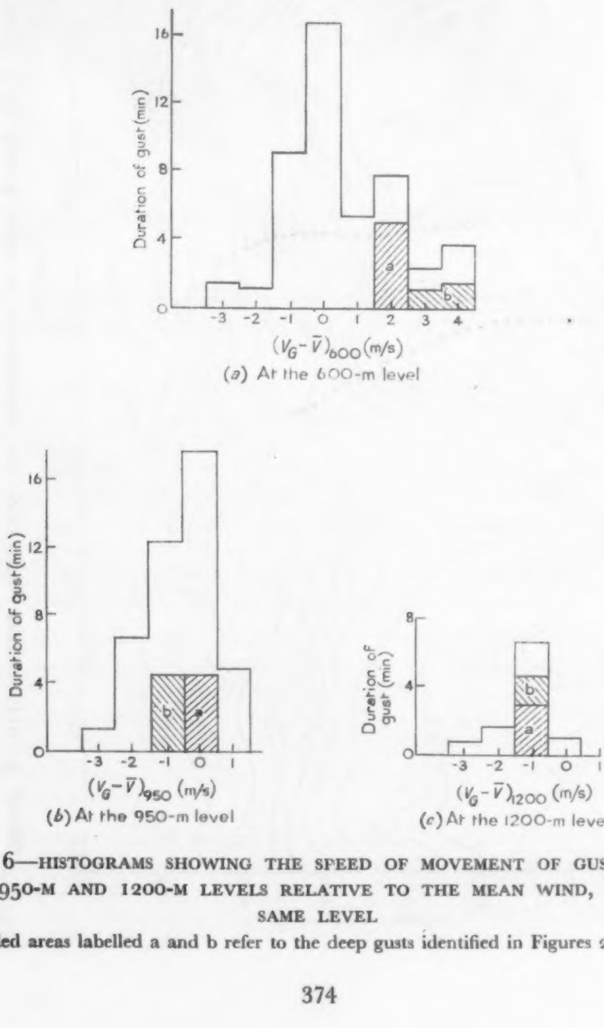

FIGURE 6—HISTOGRAMS SHOWING THE SPEED OF MOVEMENT OF GUSTS, V_g, AT 600-M, 950-M AND 1200-M LEVELS RELATIVE TO THE MEAN WIND, $\bar{V}$, AT THE SAME LEVEL

The shaded areas labelled a and b refer to the deep gusts identified in Figures 2, 3, 4 and 5.

with the wind at their level. However, the histogram is not symmetrical about the zero velocity but is positively skewed, showing that there is a tendency for some gusts to move faster than the winds at their level. At 950 m the majority of gusts again move with the wind at their level, although the histogram is now negatively skewed. At 1200 m there are fewer gusts because this level is above the 'lid' for much of the time; here all the gusts travel slower than the wind at their level. (An identical analysis for the lulls gives similar results.)

The speeds of movement of all the persistent gusts in Figure 2 are shown as boxed figures at the three heights corresponding to those of Figure 6. At 600 m there are two gusts moving with about the wind speed at this level ($\simeq$ 14 m/s) and two moving faster. The former two can be identified over only a small height range ($\simeq$ 200 m) whereas the latter two have considerable vertical extent ($\simeq$ 800 m). This suggests that two types of gusts are present at 600 m, shallow gusts which move with the wind and deep gusts which travel at the speed of the wind at a higher level. This classification is supported by other RHV sections.

It seems likely that the shallow gusts are manifestations of eddies resulting from the breakdown of the vertical shear. Such eddies do not have great vertical extent because they are sheared off by the differential velocity above and below. Eddies of this type are responsible for most of the velocity fluctuations. The reason for their absence at 1200 m (Figure 6) is probably that their formation is inhibited by the increased thermal stability near the 'lid'.

The deep gusts are less common. Most of the high velocity tail of the 600-m histogram (Figure 6), which has been attributed to the deep gusts, consists of the two gusts, aa and bb, identified in Figures 2–5 inclusive. These gusts travel at about 16·5 m/s, about the mean wind speed in the layer, 800 – 850 m, within the region of melting snow. Now, in continuous precipitation, an isothermal layer forms in the layer of melting snow near the 0°C level, and this results in an unstable layer beneath. It is difficult to relate the position and vertical extent of this unstable layer to the radar bright band in the absence of a radiosonde ascent. The only relevant observations the authors are aware of were by Brown[3] who showed that in a decaying shower the top of the unstable layer coincided with the base of the bright band. Assuming this applies to the present observations, the top of the unstable layer would be at about 850 m. Findeisen[4] reasoned that the depth of the unstable and isothermal layers depends on the duration and intensity of the precipitation and the initial stability of the atmosphere. For one hour of rain at 1 mm/h, with an initially saturated adiabatic lapse, the unstable layer would be about 200 m deep. Consequently, given an initial saturated adiabatic lapse rate we infer that the lapse would become unstable between about 650 and 850 m at the time of the RHV sections. However, although the deep gusts moved with about the mean speed of this layer, they also extended 300 m above and below it. Hence it seems plausible that the deep gusts are manifestations of overturning in an already unstable lapse beneath the weak frontal zone, and that they were 'triggered' by the layer of greater instability associated with the melting snow.

The velocity fluctuations in Figure 2 enable $\partial u/\partial x$ to be determined. If $\partial v/\partial y$ were zero, then $\partial w/\partial z = -\partial u/\partial x$ and vertical velocities (w) of several

metres per second would be expected. Observations with the aerial pointing vertically show that such large velocities were not present, thereby indicating considerable transverse motion.

Conclusions.—Doppler radar measurements of the *u* component of the horizontal wind on an occasion of steady precipitation have shown distinct velocity perturbations. Below 300 m these had an amplitude of at most about 1 m/s. Above a 'lid' near 1200 m the flow was relatively smooth. Between these two levels perturbations of several metres per second were present. These could be divided into shallow eddies, moving with the mean wind speed at their level, and deep eddies travelling at the speed of the wind at about 825 m. The former were probably caused by breakdowns of the shear layer whilst the latter may have been a manifestation of overturning in an unstable layer.

In order to clarify the relationship of the velocity fluctuations to the temperature structure, future studies will be supplemented by special radiosonde ascents made at frequent intervals from Pershore.

Acknowledgements.—The authors wish to thank Messrs S. R. Smith and J. Reeve for maintaining the Doppler radar, and Miss Wendy Smith and Messrs G. Lowe and D. Membery for their assistance in collecting and analysing the data. The paper is published with the permission of the Director-General of the Meteorological Office, and the Director, Royal Radar Establishment.

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REVIEWS

Some methods of climatological analysis, WMO Tech. Note No. 81, by H. C. S. Thom. 11 in × 8½ in, pp. xii + 53, *illus.*, Secretariat of the World Meteorological Organization, Geneva, 1967. Price: Sw. fr. 6.00.

This Technical Note was prepared by a Working Group of the WMO Commission for Climatology following its meeting in London in December 1960. The work consists of three chapters.

The first chapter dealing with climatological series emphasizes the need for care in ensuring that a climatological series being subjected to statistical examination is in fact homogeneous; it points out that some apparently multimodal distributions arise from series wrongly selected from two or more distinct populations. Some simple examples of the calculation and presentation of empirical frequency and cumulative distributions are given as well

as a test for homogeneity in which the actual frequencies of runs of values above and below the mean are compared with the frequencies expected if the series is homogeneous. These expected values are, however, merely quoted, with no indication of how they are derived.

Chapter two is very short, consisting of a descriptive list of the common statistics, mean, standard deviation, mode and so on. Where appropriate, formulae are given for these quantities. The distinction between a statistic (derived from a sample) and a statistical parameter (a function of all the population values), is emphasized.

Chapter three, entitled 'General statistical methods' deals with a number of the well-known frequency distributions to one of which a climatological series can usually be fitted. The formula and parameters for each distribution are stated, without derivation or 'proof'. Then follow sections on simple and multiple correlation, regression and analysis of variance. Throughout the chapter each section is illustrated by a worked example. Significance tests are barely mentioned, neither are any tables given for use in applying these tests or for estimating frequencies from the theoretical distributions.

This is not a work on statistics in general but is concerned only with the analysis of series of climatological (random) variables. It is essentially practical, with emphasis on the empirical treatment of the data, though theoretical distributions are recommended where their use is justified. The text demands very careful reading especially in the early parts of the chapters dealing with general principles. To a reader with no knowledge of statistics this Technical Note will convey very little but it is a useful aid to the climatologist having the necessary background knowledge and access to the well known statistical textbooks.

A. G. FORSDYKE

The depth of cold, by A. R. Meetham. 8 in × 5½ in, pp. 173, *illus.*, The English Universities Press Ltd., St Paul's House, Warwick Lane, London EC4, 1967. Price: 25*s*.

'The depth of cold' is the somewhat curious title of a book in the New Science Series, the General Editor of which is Sir Graham Sutton now Chairman of the Natural Environment Research Council. The book covers a wide variety of topics ranging from naturally occurring low temperatures at the earth's surface and at great heights to artificial cooling for the home, for industry and for the laboratory.

The meteorological content is small being confined to some discussion of extremely low surface temperatures, survival in the cold and a chapter on 'Snow, ice and ice ages'. The suggestion, that the average lapse rate of 1 degF in 280 ft can be applied to the *minimum* temperatures observed at a place to estimate the minimum temperatures which might occur at a mountain top, ignores the fact that surface minima are always associated with surface temperature inversions. The discussion of the formation of ice crystals in the atmosphere is superficial and misleading and the implication that clouds are all ice at temperatures below 0°C is extraordinary.

Of greater interest are the chapters on the industrial applications of cold and the laboratory experiments towards the absolute zero of temperature. The level of writing is variable, verging on patronising at times, but it must be admitted that making popular science of superconductivity, phonons, quantum theory and the like is a difficult task.

R. F. JONES

Probleme der Wettervorhersage, edited by F. Steinhauser. 9 in × 6½ in, p. 161, *illus.*, Springer-Verlag, Wien, 1966. Price: $13.25.

In September 1965 a symposium was held in Vienna to celebrate the centenary of the publication of the first Austrian weather chart and also the centenary of the founding of the Austrian Meteorological Society. The papers which were presented at this conference are gathered together in this volume (with the exception of one by Holmboe which has already appeared in *Tellus*). The list of contributors contains the names of many meteorologists with international reputations, and the various papers cover a wide range of problems of weather forecasting.

In the first paper Bjerknes explains how an incipient depression can develop on the polar front. In the next paper Palmén discusses the vertical flux of energy between 1000 mb and 100 mb in the region between 32°N and the north pole and summarizes his calculations in a disarmingly simple diagram which gives no hint of the amount of work which went into producing it. Then, Scherhag discusses the abnormal behaviour of two depressions; one which sticks in his memory, because of the catastrophic Hamburg floods, will probably be better remembered by British meteorologists on account of the Sheffield gales. Scherhag attributes the abnormalities in the behaviour of both depressions to abnormal circulation at 100 mb.

The next four papers are concerned with various aspects of meteorological organization. Then there follow three papers on theoretical aspects of forecasting: the filter problem in numerical forecasting, the problem of baroclinic instability in zonal and meridional flow and the retrogression of divergence-free waves. Next there are four papers on long-range forecasting, including one in English by Namias; this is a comprehensive review of American practice and has a list of over 90 references. These are followed by a short paper by Schilling on predicting the state of the atmosphere above 80 km; Schilling is careful to state that this cannot yet be classed as weather forecasting and he avoids the use of the word weather in this context. The volume concludes with a paper by Miles (in German) on medium-range forecasting in Great Britain.

This volume, therefore, contains something for forecasters of every kind — for conventional synoptic forecasters, long-range and medium-range forecasters and for those who have to organize and teach forecasters. The layout of the text and printing have the elegance and clarity which are always associated with the firm of Springer, though some of the diagrams have been so greatly reduced in reproduction that details are impossible to read.

S. E. VIRGO

International meteorological tables, WMO Tech. Paper No. 94, edited by S. Letestu. 10 in × 7½ in, Secretariat of the World Meteorological Organization, Geneva, 1966. Price: Sw. fr. 20.

As a handbook of numerical values used by the practising meteorologist these tables have superseded the original International meteorological tables first published in 1890 and not since revised, though supplemented from time to time by additional tables prepared by individual meteorological services. A new set of tables became necessary for several reasons. These include the need for tables of a rather wider scope than those formerly in use, occasioned for example by the extension of synoptic charts to the vertical dimension, so that in the new tables much space is given to values of atmospheric thickness between various surfaces of constant pressure; the adoption of new values of physical units and constants resulting from advances in knowledge and more refined experimentation; and the increasing need for international standardization.

The work is divided into two parts: first the values of the various fundamental units and physical constants and explanatory matter for the tables, and then the tables themselves. This division, though perhaps advantageous when amendments and additions become necessary (facilitated by the loose-leaf method of binding), is less convenient to the reader than the alternative of placing each table adjacent to its own explanatory section.

The tables need only brief mention, to indicate the scope of the volume. The units are, for the most part, those of the International System of Units (metre, kilogramme, second . . .), but the first table gives a comprehensive list of factors for conversion to many other national units, e.g. the knot, yard, mile, gallon, millimetre of mercury, and so on. A table of Beaufort wind scale equivalent wind speeds follows, but a warning is given that these have not yet met with general approval. The rest of the tables are divided into three main sets. These deal with: atmospheric dynamics, e.g. geostrophic and gradient winds; atmospheric statistics, e.g. geopotential in relation to geometric height, atmospheric thickness between various constant pressure surfaces, international barometer conventions; and atmospheric thermodynamics, e.g. thermodynamic constants and functions, and thermodynamic properties of water vapour. These last tables do not include one for use with dry-bulb and wet-bulb thermometers, and the various humidity properties obtained from their readings need to be calculated from the tabulated values of vapour pressure, using a suitable hygrometric formula.

Though the tables are eminently useful for practical purposes the more interesting parts of this volume are the explanatory notes, called 'Introductions'. These put the whole system of meteorological units on a firm and unambiguous basis. The definitions of some units may seem obscure to the practical meteorologist, and indeed incomprehensible to one of the older generation. For example, the metre is defined as 'the length equal to 1,650,763·73 wavelengths in a vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the atom of krypton 86'. One feels at home still in thinking of the metre as the length of a prototype standard bar. But the need for an unambiguous definition is recognized, and if these tables standardize usage in the many meteorological services and institutions of the world their preparation and publication under an international body will have been well worth-while.

A. G. FORSDYKE

Advanced seminar on spectral analysis of time series, edited by B. Harris. 9¼ in × 6½ in, pp. x + 319, *illus.*, John Wiley and Sons Ltd, Glen House, Stag Place, London SW1, 1967. Price: 64*s*.

This volume contains the text of 10 papers presented at a seminar at the University of Wisconsin on 3–5 October 1966, with an explanatory introduction by the editor, Bernard Harris. It seeks to present a survey of the basic theory of spectral analysis of time series, together with an account of significant recent developments. The authors include several with international reputations, and the general standard of presentation is that of discussion between experts. J. W. Tukey, writing on the calculations of numerical spectral analysis, says more in fewer words than most of the contributors, and does so with clarity and verve. He is very forthright about the merits of the fast Fourier transform procedure. H. A. Panofsky, in the only paper dealing with meteorological data, summarizes the meteorological applications of cross-spectral analysis in a way which should suit non-meteorologists and meteorologists requiring a general view, with references for those who must look deeper. Brillinger and Rosenblatt, in two papers making up nearly a third of the book, cover the theory, computation and interpretation of k^{th} order spectra, and illustrate their work with a massive analysis of the Zurich sunspot numbers, using the fast Fourier transform and the London University Atlas computer. However, while they give a clear account of the features of the series which can be seen on a well-proportioned graph, they are less explicit about the conclusions to be drawn from their extensive computer operations. Perhaps this enigmatic series was an unfortunate choice of test material, or maybe the sheer bulk of results defies condensation: at any rate their treatment shows what can be done in the way of analysis. Box, Jenkins and Bacon, in a paper which makes no mention of spectral analysis, discuss models for forecasting seasonal and non-seasonal time series. Their account illustrates the point that this is a field of study in which mathematical ingenuity is no substitute for practical experience.

Mention of these contributions by name should not be construed as an unfavourable comment on the remainder since all the writers give evidence of familiarity with real problems and make thoughtful contributions towards their solution. Each contribution has a good list of references. The student of time series should find this a valuable reference, either giving him what he needs, or showing him where to find it. The excellence of the printing and the high standard of the contributions make this book a pleasure to review.

J. M. CRADDOCK

NOTES AND NEWS

Weather recording instruments on a television mast

At Belmont, Lincolnshire, a 1265-ft mast constructed for the television authorities came into use in May 1966 and during the summer of 1967 weather recording instruments were installed at various levels by the British Insulated Callender's Construction Company Ltd for investigations by the Central Electricity Research Laboratories (Plates III and IV). Readings from the instrument will be scanned and transmitted over a telephone line to a distant

station for recording and subsequent analysis by means of a data logging system. Readings from some of the instruments will also be fed into the telemetry system of a Meteorological Office automatic weather station and the readings will be made available for use at the forecast office at Manby, and elsewhere in the Meteorological Office.

Standard Mark 4 Meteorological Office anemometer systems are used to obtain wind speed and direction and are installed on the external maintenance platforms at 1252 ft and at 680 ft. The uppermost instrument is at the top of a mast made of two 10-ft sections, and at 1272 ft above ground is the highest recording instrument supported by a permanent structure in Europe. At the 680-ft level, the anemometer is supported at the end of a 12-ft horizontal steel boom braced from the external platform.

Vertical and horizontal gustmeters are mounted at 1252 ft and at 680 ft on 12 ft horizontal steel booms stayed with steel wires to the platform.

Thermometer boxes, containing for example wet-bulb and dry-bulb thermometers, are supported on the floors of the external platforms at heights of 1252 ft, 680 ft, 460 ft and 100 ft. Two other thermometers are used, one inside a glass fibre cylinder at 900 ft and the other on the outside of a steel cylinder at 30 ft.

Frozen Sea at Hunstanton

We are indebted to Mr Cram for obtaining the photograph of frozen sea at Hunstanton (see Plate II). It was taken from a point about 200 yd out to sea, near the pier and facing south-east. The ice, sometimes as much as 6 ft deep, consists of hard sheets or blocks mixed with soft broken ice as seen at the top left of the photograph. The tide was probably 600–700 yd out.

Practically all the ice disappeared during the temporary thaw of late January 1963.[1]

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1. LAWRENCE, E. N.; Soil temperatures during the frost of early 1963 in south-east England — Part I. *Met. Mag., London*, **93**, 1964, p. 17.

Hellenic National Meteorological Service

Brigadier General P. Karayannis has been appointed Director General of the Hellenic National Meteorological Service.

Meteorological Magazine: price increase

As from January 1968, the price of an issue of the *Meteorological Magazine* will be 3*s*. 6*d*. and the annual subscription will be £2 7*s*. including postage.

OBITUARIES

It is with regret that we have to record the deaths of Mr R. Plawinski (S.A.) on 15 June 1967 and Mr I. C. Revill (S.A.) on 18 August 1967.

OFFICIAL PUBLICATION

The following publication has recently been issued :

Handbook of weather messages, Part II. Fifth edition. London, HMSO, 1967. Price 15*s* 6*d*.

Recommendations which were made by the Commission for Synoptic Meteorology at Weisbaden in April 1966, and which were approved at the eighteenth session of the Executive Committee of the World Meteorological Organization at Geneva in July 1966 necessitate changes in some of the code forms and specifications to be used in surface and upper air reports, forecasts and analyses with effect from 1 January 1968. This new edition of the Handbook of Weather Messages Part II incorporates these changes.

Among the changes introduced are two new codes, one for routine weather reports and the other for reports of sudden changes for civil aviation purposes. These code forms depart from the usual five figure groups, and groups of between two and seven figures as well as letters are to be found in coded messages. The upper air codes have been completely redesigned. The two groups which give a ship's position have been expanded in all ship messages into three groups and there is provision in these codes to report air and sea temperature to one tenth of a degree Celsius.

CORRIGENDA

Meteorological Magazine, August 1967, p. 226, for '. . . total resistance as seen by . . .' read '. . . total resistance variation as seen by . . .'.

Meteorological Magazine, September 1967, p. 268, temperatures in Table V are measured in degrees Fahrenheit, not in degrees Celsius.

THE METEOROLOGICAL MAGAZINE
VOL. 96 NO. 1145 DECEMBER 1967

CONTENTS

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and published by
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Three shillings monthly **Annual subscription £2 1s. including postage**
Dd. 133110 K16 12/67 S.O.Code No. 40-43-67-12